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Correlated Shadow-Fading in Wireless Networks and its Effect on Call Dropping

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Abstract. We discuss a statistical model to generate correlated shadow-fading patterns for wireless systems in the absence of detailed propagation and landscape information. The currently available autocorrelation models result in anomalous effects that depend on traffic density and mobility, as they propose independent random processes for each mobile. Our approach involves generating a pre-computed fading map with the right marginal distributions and spatial correlations, which avoids inconsistencies such as providing widely differing values for mobiles close to each other. The correlations are introduced via a Gaussian random field, which has a covariance structure that depends on a set of parameters which can be computed from local measurements. The model is efficiently implemented using standard linear-algebra methods. We conclude by describing a simulation experiment to study the effect of correlations on call dropping. The experiment reveals a strong relationship between call dropping and the correlation length of the fading pattern, and indicates circumstances under which dropping may be relatively high.

Keywords: shadow-fading, correlation, propagation model, wireless, statistical physics

1. Introduction

Propagation is a crucial factor in the design and performance of wireless systems. There are several statistical methods to estimate propagation under different conditions, and most of these methods are computationally intensive. 2D and 3D ray tracing methods, for example, are popular techniques with much effort devoted to enhance their computational viability (see [2,7 and references therein]). Inaccuracies in modeling specific aspects of propagation, such as shadow-fading, could lead to distorted capacity and performance estimates in simulations and approximate analytical calculations. Shadow-fading is the slowly varying component of propagation that arises, as the name suggests, primarily from obstacles. Rayleigh fading, which is a propagation variation on a smaller scale, is also an important factor for stationary or slow moving users of the wireless system, but we do not deal with it here.

For some applications, it is useful to have a statistical model of propagation with an empirical validity for the conditions of interest. It is in this spirit that the log-normal distribution, which is most widely used at the present, was proposed. In this model, the received power at each location is assumed to be independent of other locations and log-normally distributed about a deterministic large-scale decay, i.e.,

$$P(r) = P_0(r)\,\mathrm{e}^{s}, \tag{1}$$

where s is normally distributed with mean 0 and $\log P_0(r)$ is the average value of $\log P(r)$ received at distance r from the transmitter after large-scale fading. Usual forms for this function are $P_0(r) = A + B\ \log(r)$ (the Hata model [5]) or simply the power law decay $P_0(r) = K/r^d$, where A, B, K and d are specific constants depending on the environment. While these models are simple and account for the observed marginal distributions, they fail to capture the spatial correlations inherent in shadow-fading, which cause its slowly-varying behavior. Simulations of wireless systems that ignore such spatial correlations could give seriously misleading results, as we illustrate below with an example of a call drop rate calculation.

Our interest in generating realistic shadow-fading patterns arose in the context of a simulation study of a novel Interference-Based Dynamic Channel Assignment algorithm [1]. The proposed algorithm relies on periodic interference measurements on the inactive frequencies so as to identify appropriate candidate channels. To obtain accurate estimates of the impact on system capacity and voice quality, we were confronted with the problem of generating shadow-fading values consistent with specified marginal distributions and correlation parameters.

The issue of capturing correlations in shadow-fading has been addressed previously by Gudmundson [3,4] by means of an auto-regressive model that approaches the issue differently. The correlations considered there are between the shadow-fading values seen by a mobile as it moves in the environment. In simulations, this would imply independent random processes for each mobile admitted to the network. Thus, one encounters anomalies such as the assignment of completely different shadow-fading values for different mobiles at nearby locations or at different times at the same location.

In this work, we take Gudmundson's empirical observations about the marginal distribution and correlation structure as valid. We hence do not present any additional experimental data or measurements. Instead, we focus on the observation that the data obtained from measurements may be better fit by a *2-dimensional* model, rather than the 1-dimensional one proposed by Gudmundson. One possible effect